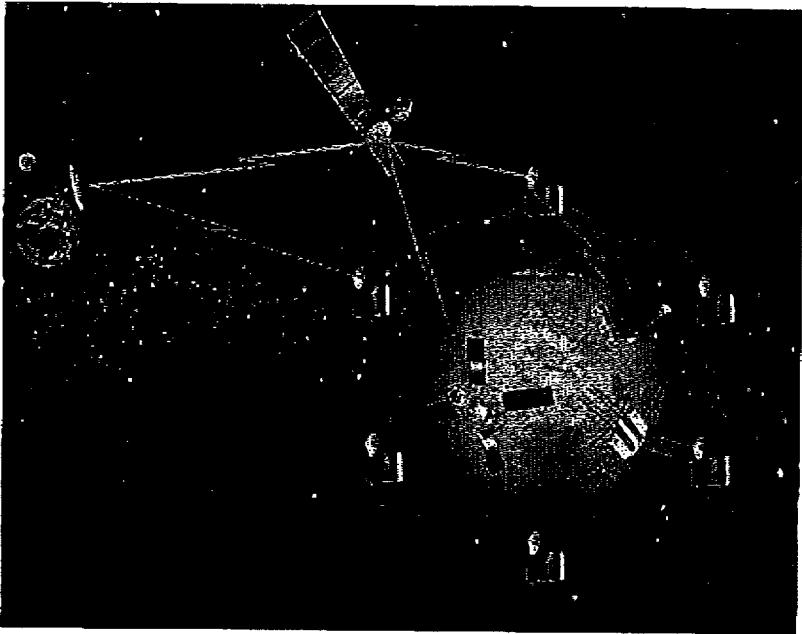


Mars Network: An Infrastructure to Support the In Situ Exploration of Mars



JPL



Chad Edwards

November 17, 1999

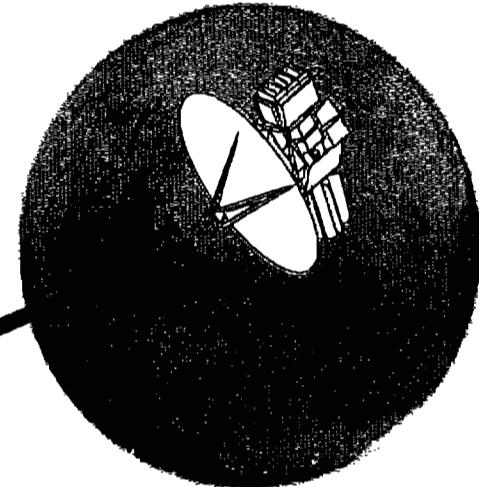
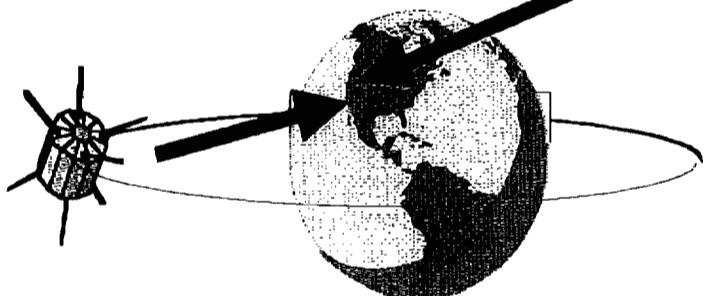
**1999 American AAS National Conference and 46th Annual Meeting
Pasadena, CA**

**Mars Network Project Office
chad.edwards@jpl.nasa.gov**



Telecommunications

- Communications performance decreases as the square of distance
 - Mars-Earth distance can reach over 2.5 AU (~400 million km)
 - Typical GEO Earth communications satellite is only about 40 thousand km away
 - It's about 80 dB (or 100,000,000 times) harder from Mars!



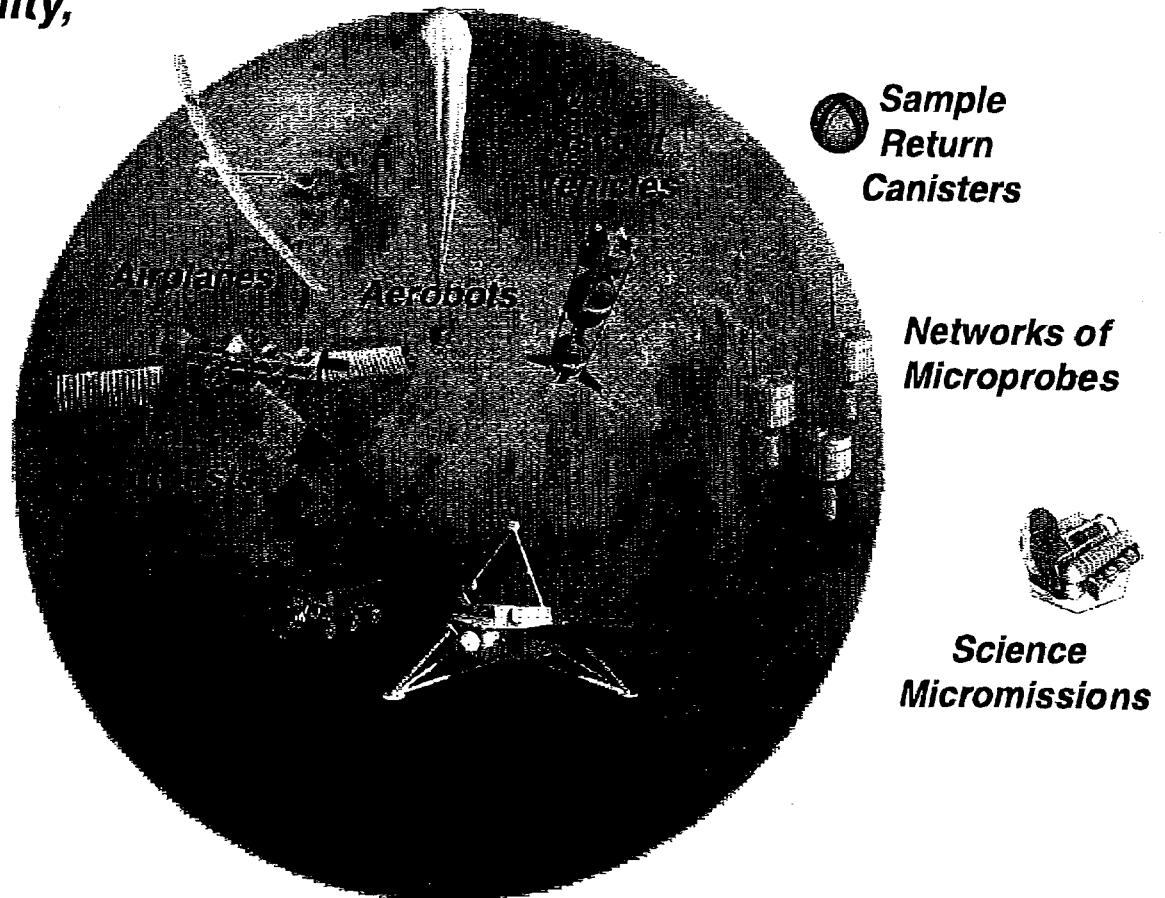
Operations

- Large distance implies long round trip light time (RTLT)
 - RTLT varies from ~ 10 min up to ~40 min
 - RTLT >> seconds
 - No "joysticking" or "teleconferencing"
 - Need for high levels of autonomy at Mars
- At the same time, RTLT << 1 sol
 - Sci/Eng teams on Earth can interact with Mars assets many times per sol, if infrastructure allows

The Coming Decade of Mars Exploration



- *Highly diverse spacecraft
(size, power, mobility,
lifetime, ...)*
- *Globally
distributed
missions*
- *Complex
surface and
orbital operations*
- *Evolving
capabilities*



Key Considerations for Mars Communications



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- **Increased data return for virtual presence**

- Pathfinder: Direct-to-Earth link returned 30 Mb/sol
 - Corresponds to only 300 bps time-averaged Mars-to-Earth bandwidth
- Future: Increased data return to enable new science and increased public outreach
 - Frequent full-resolution Pancam images (~1 Gbit/image)
 - Streaming video (~1 Mb/s) for long range rovers, aerobots
 - High-resolution 3-D representations of surface geology



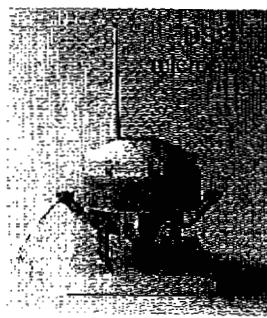
- **More frequent contact to support complex surface operations**

- Pathfinder direct-to-Earth link provided only few hrs/sol contact (energy-limited)
- Polar science orbiters provide only one or two 5-min contacts/sol
- Frequent contact allows rapid closed-loop planning with sci/eng teams



- **High-sensitivity relays for micromprobes, microlanders, ...**

- Pathfinder Direct-to-Earth link required high mass (>15 kg to surface), and high energy-per-bit (500 W-hrs/Gbit to 70m DSN antenna)
- Relay links enable much lower mass (~ 1-2 kg or less) and reduced energy-per-bit (~5-10 W-hrs/Gbit) w/ UHF omni



- **Improved navigation for new mission concepts**

- Pathfinder landing error ellipse ~ 100 km
- Targeting future landers to specific sites of geological/biological interest will require sub-km precision landing capability
- Sample return drives new capability for in-orbit rendezvous & docking



...all this with programmatic reliability, resiliency, flexibility, and evolvability...

Systems Engineering Approach for Mars



Goal:

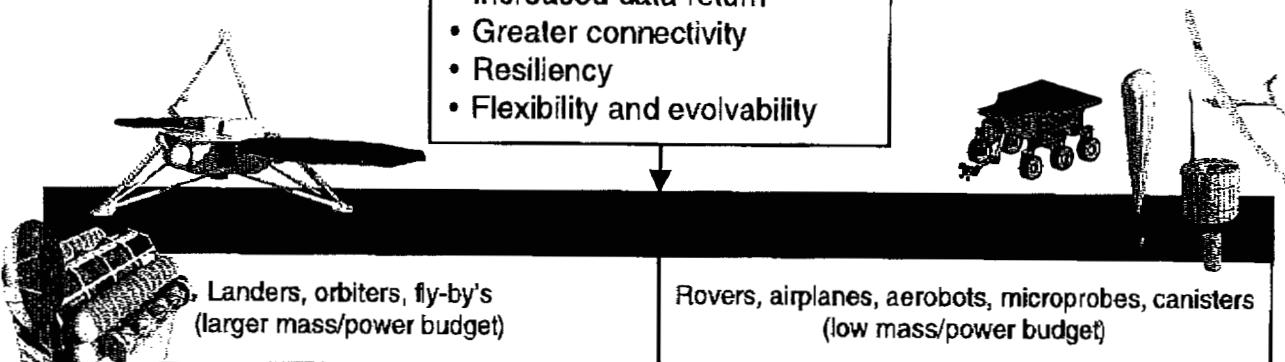
Create a virtual presence and support robust exploration at Mars

Requirements:

Provide:

- Increased data return
- Greater connectivity
- Resiliency
- Flexibility and evolvability

Assets to be Supported:



Options:

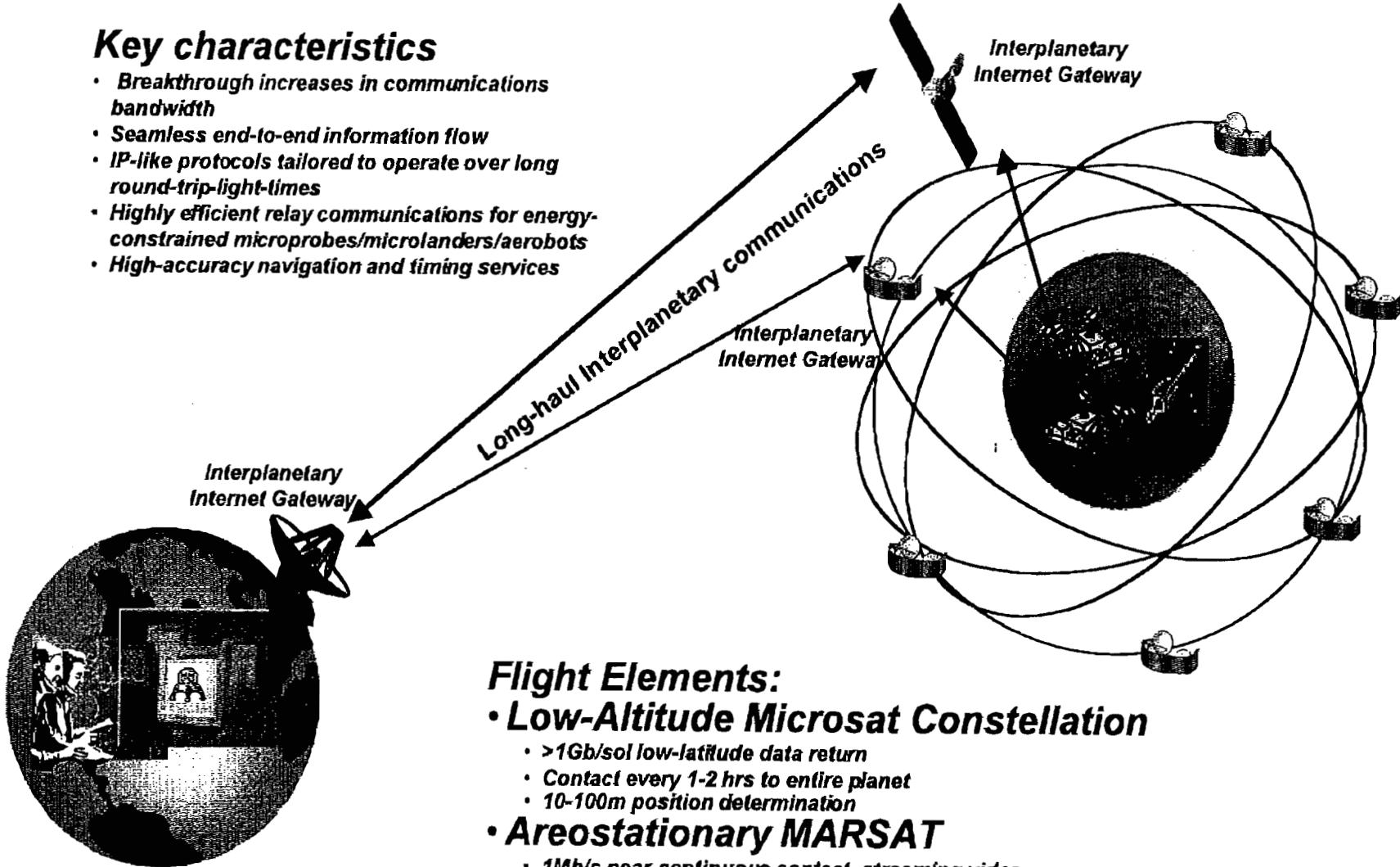
Mars Network

Common Solution

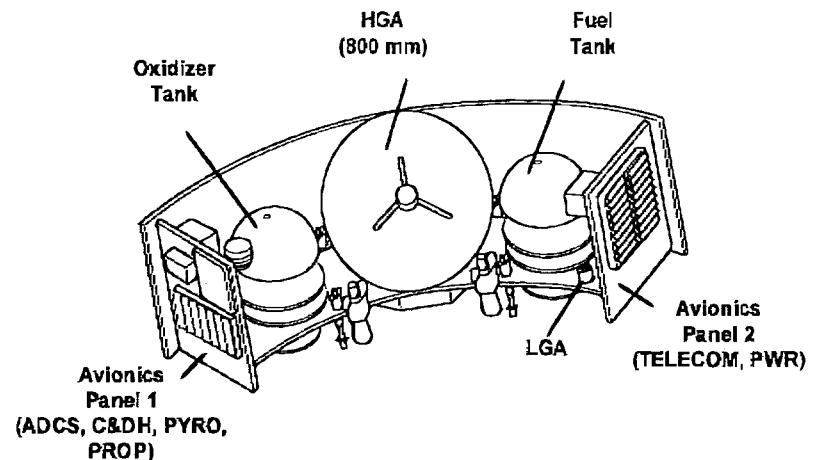
- Enhancing capabilities for larger vehicles (increased data return and connectivity, more mass/power for science payload)
- Enabling capabilities for whole new classes of small vehicles

Key characteristics

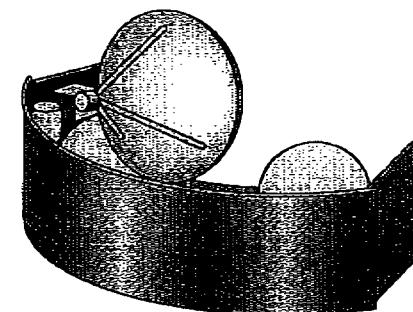
- Breakthrough increases in communications bandwidth
- Seamless end-to-end information flow
- IP-like protocols tailored to operate over long round-trip-light-times
- Highly efficient relay communications for energy-constrained microprobes/microlanders/aerobots
- High-accuracy navigation and timing services



- Low cost, single-string, 3-axis stabilized design
- Common bus design, also applicable to Mars science probe/orbiter missions, to be developed by Mars Micromissions Project
- Piggyback launch on Ariane 5 Structure for Auxiliary payload (ASAP)
- 220 kg mass, 250 cm x 60 cm x 80 cm
- X-band Earth link--standard DSN link; volume-constrained 80-cm HGA
- UHF proximity link for *in situ* communications and navigation

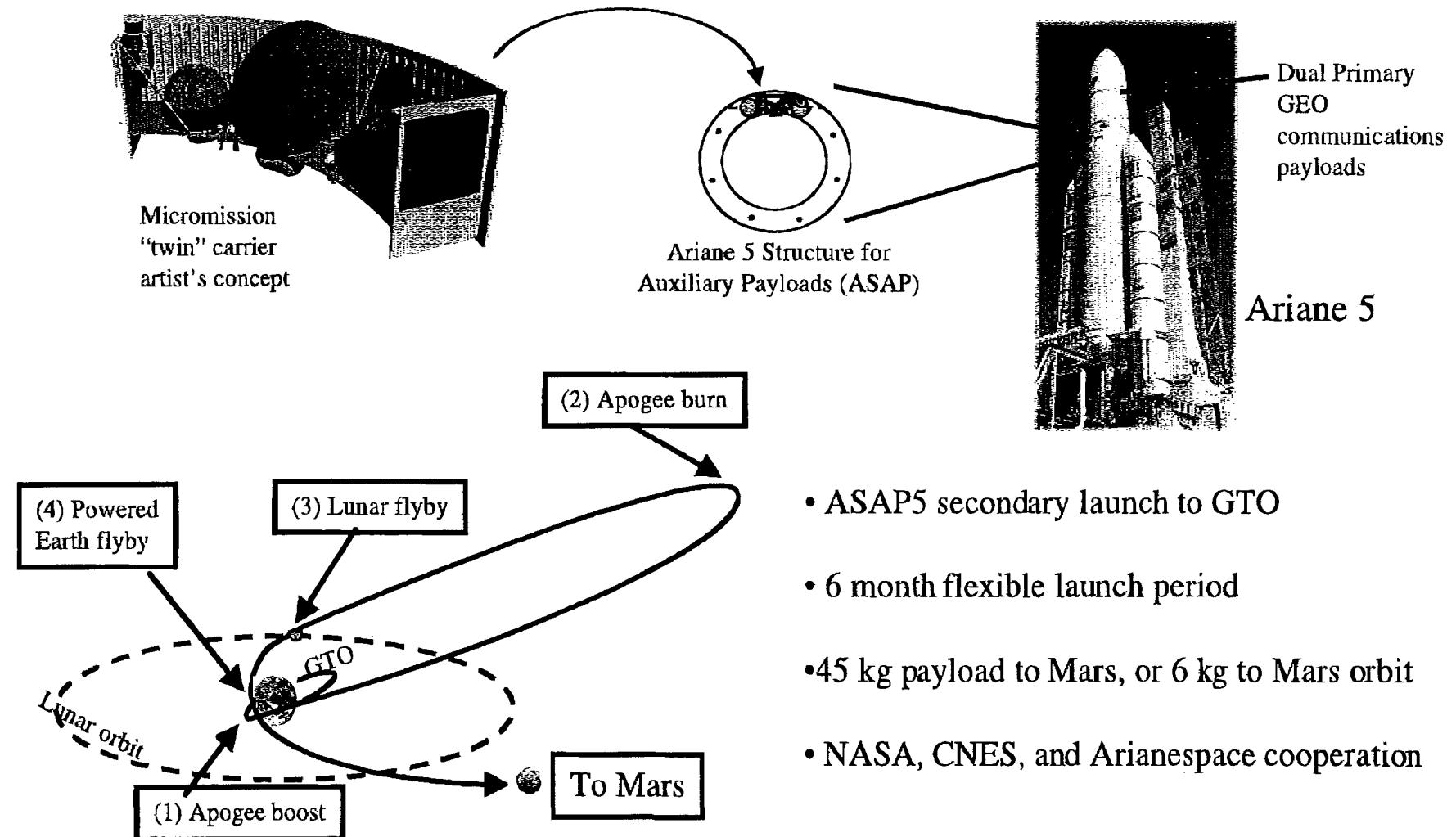


Launch Configuration



Deployed Configuration

Mars Micromissions Using Ariane 5

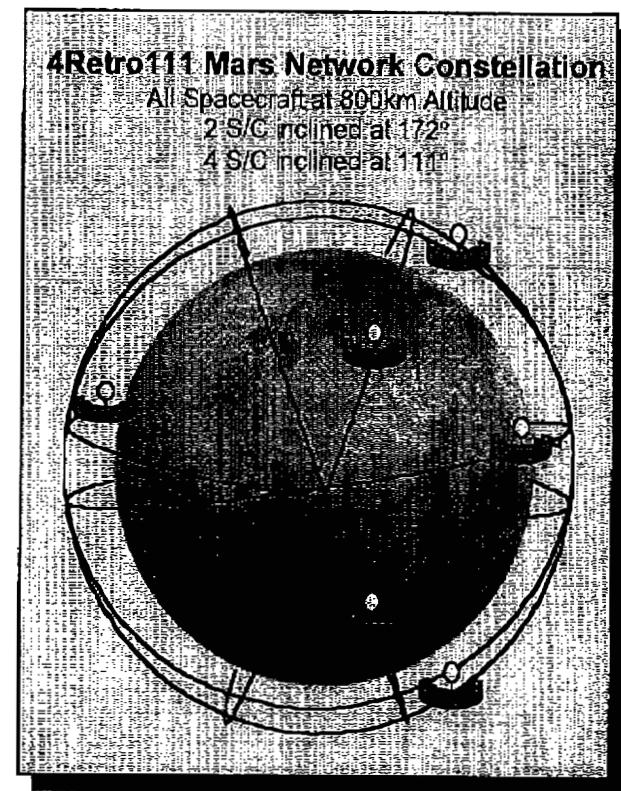
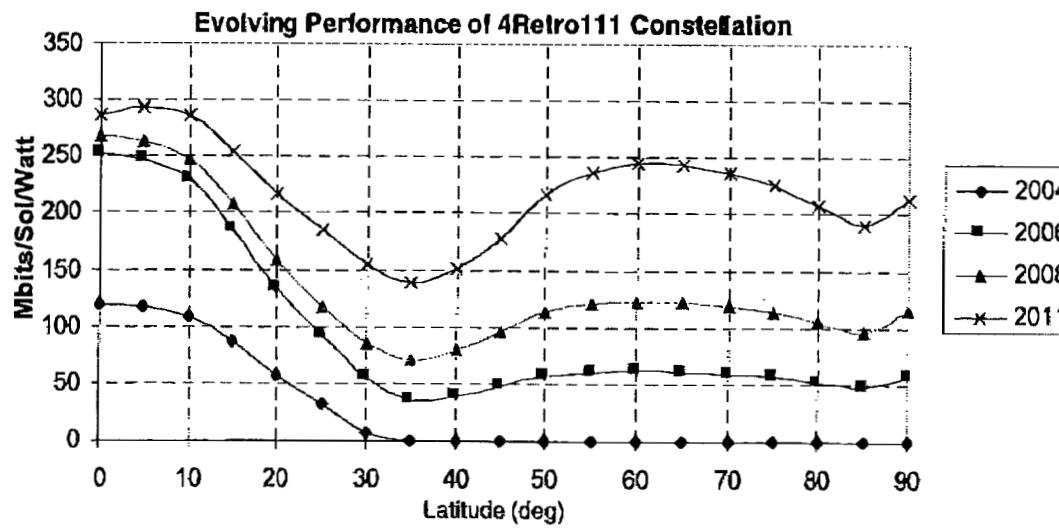


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- Proposed six-satellite constellation is motivated by optimizing key figures of merit
 - data return/sol/W
 - contacts/sol
 - maximum gap times
 - navigation performance



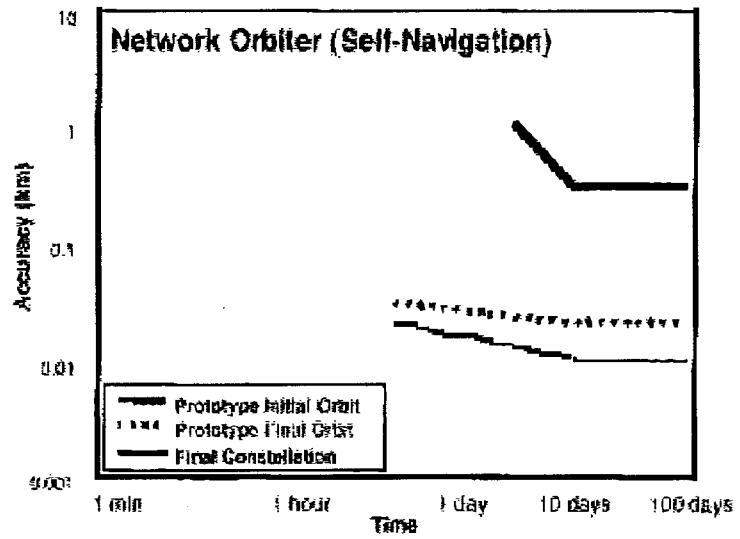
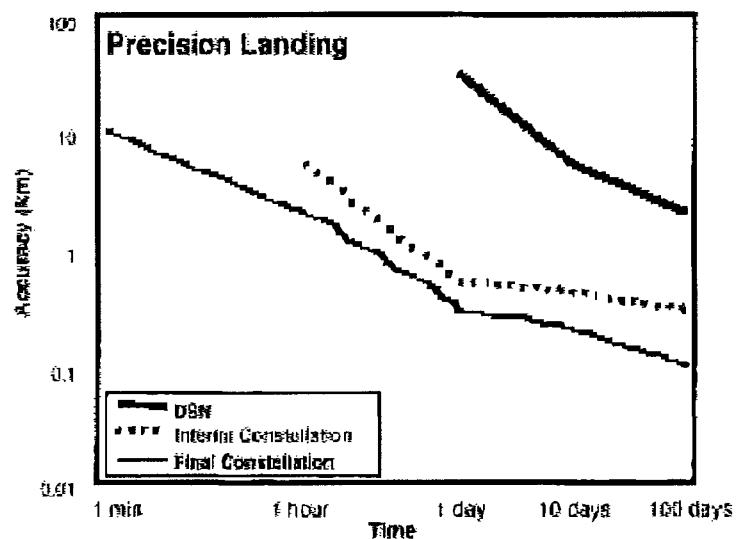
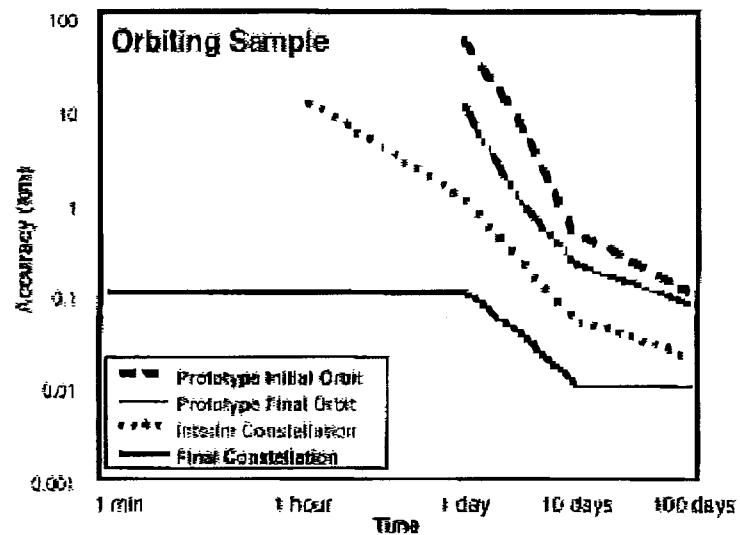
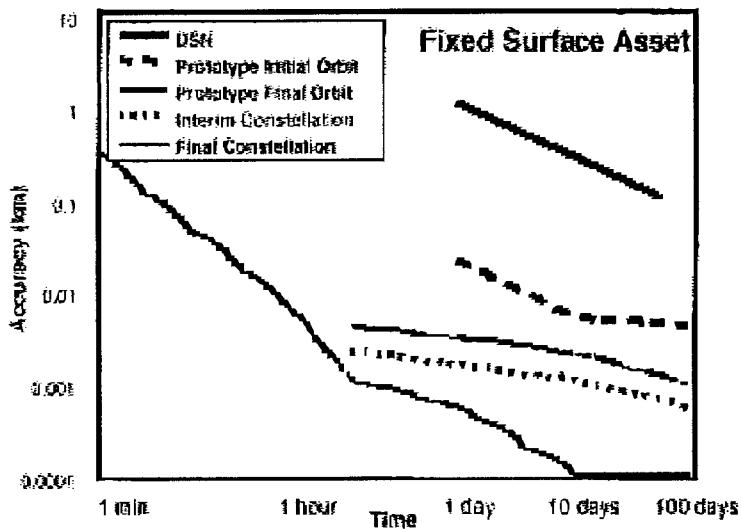
Mars Network: Navigation Performance



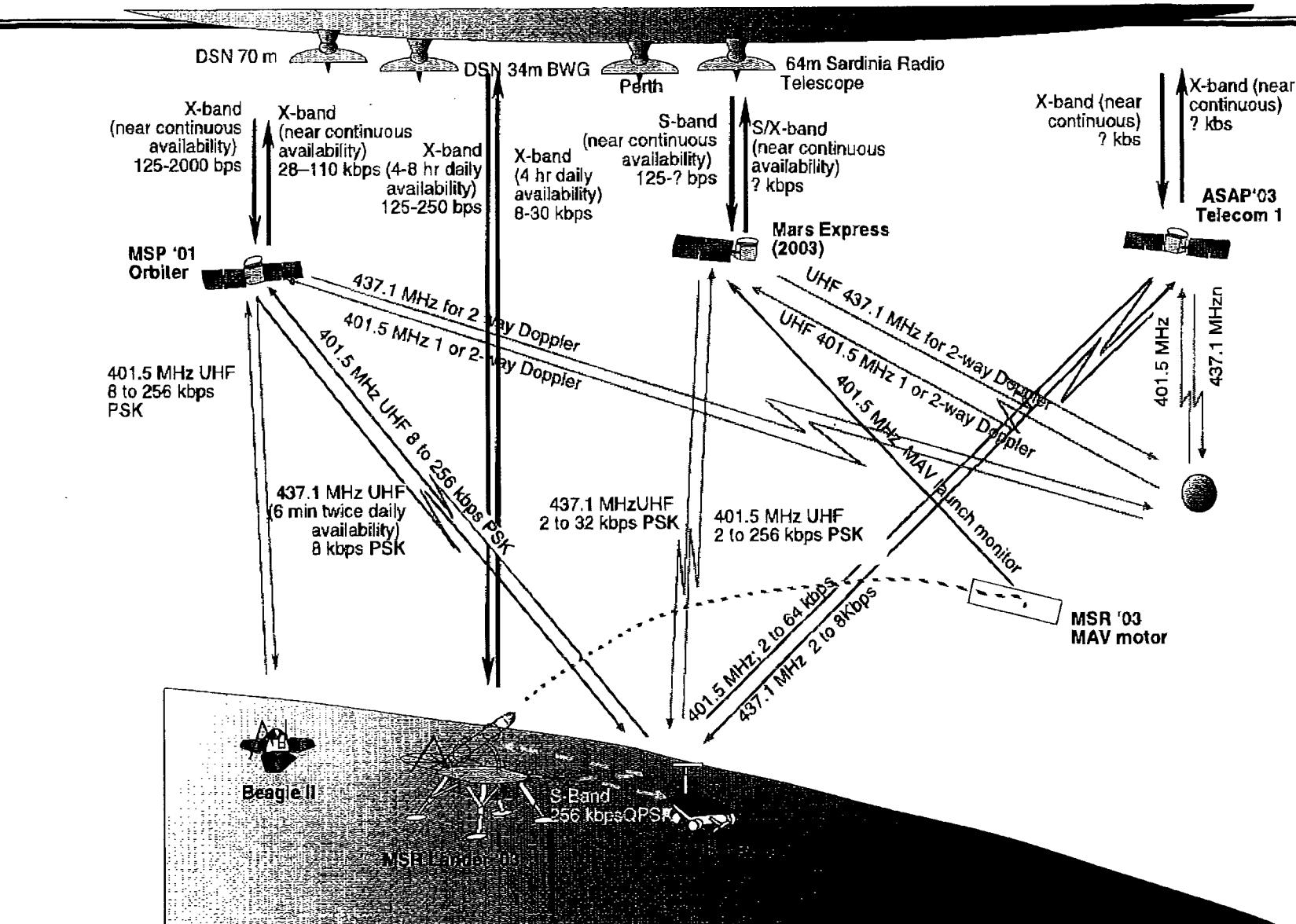
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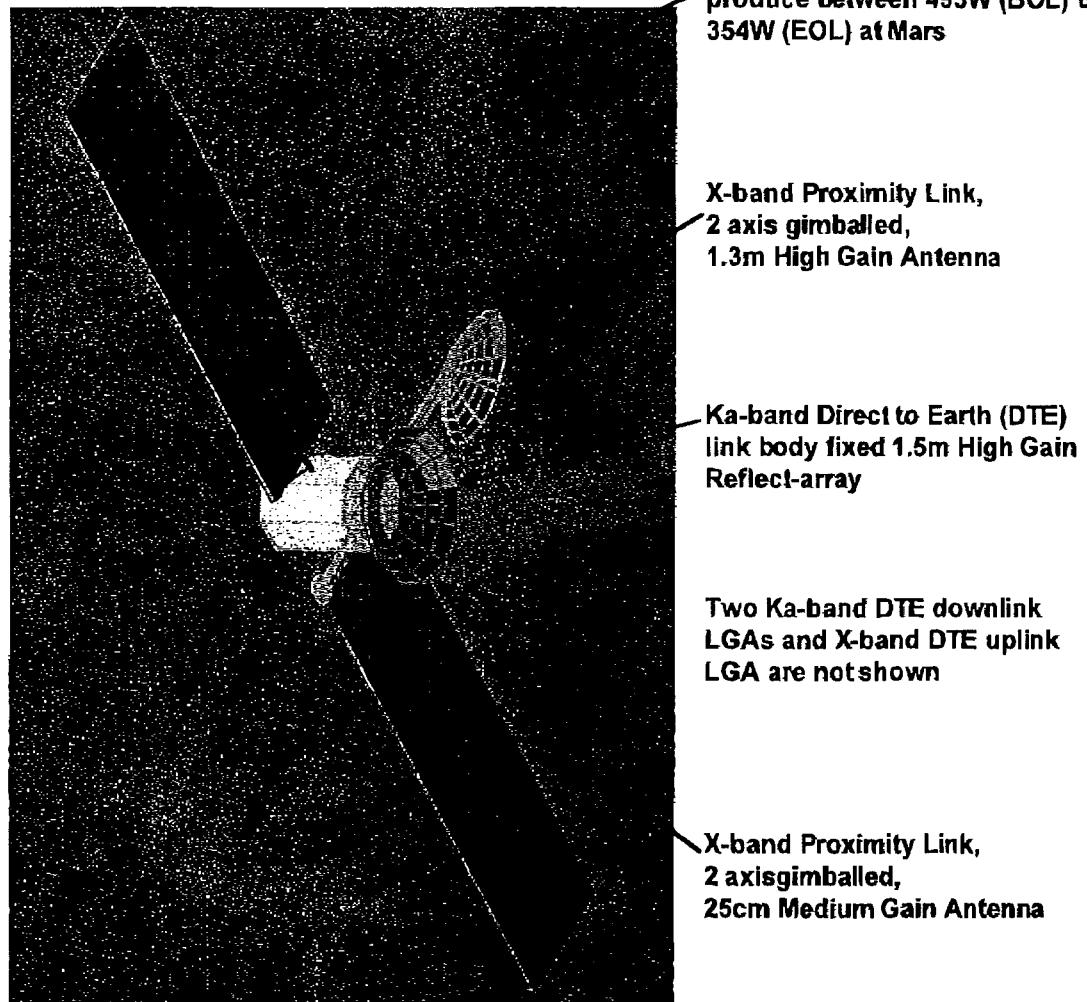
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Planning View of '04 Mars Relay & Orbital Communication Architecture



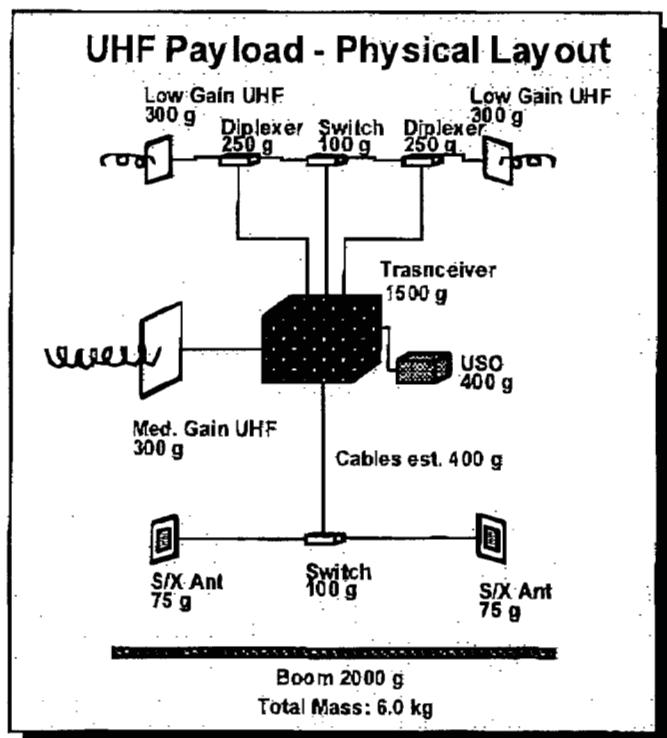
- Communications asset for breakthrough increase in bandwidth & connectivity
- Ka-band Earth link; X-band in-situ link
 - One high-rate (> 1 Mbps) link from orbiter to Earth
 - One high-rate (~ 1 Mbps) link from science element
 - Several lower data rate (20 kbps) links from science elements on Mars to orbiter
 - Landed elements use small, low power, components, e.g., 2W SSPA; 20cm, 22 dBi directive antenna
- Delta II launch
- 808 Kg mass
- 7 year life
- Deployed similar to Earth geostationary satellite; near continuous comm



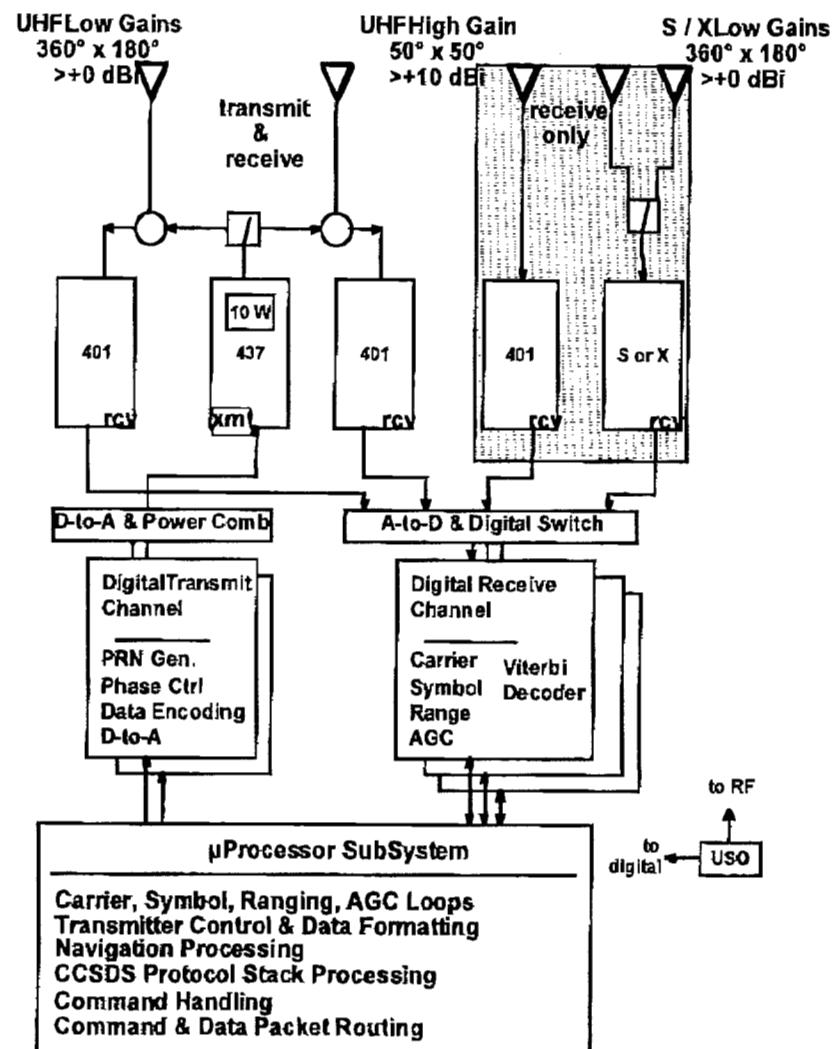
Mars Network Proximity Link UHF Payload Point Design



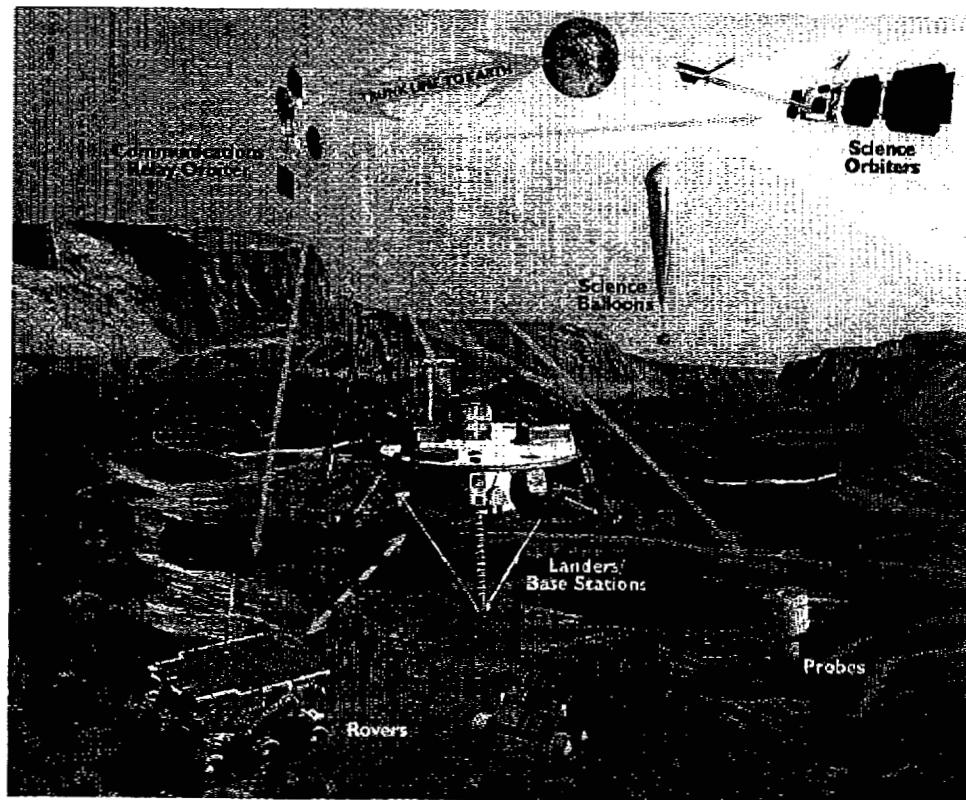
- Microprocessor-based transceiver design
 - Heritage to JPL GPS rcvr, DS3 AFF
 - Highly software-based architecture provides post-launch evolvability over s/c lifetime to accommodate new protocols, new users, ...
- 10 dBi UHF antenna for enhanced pre-aerocapture capability



Payload Block Diagram

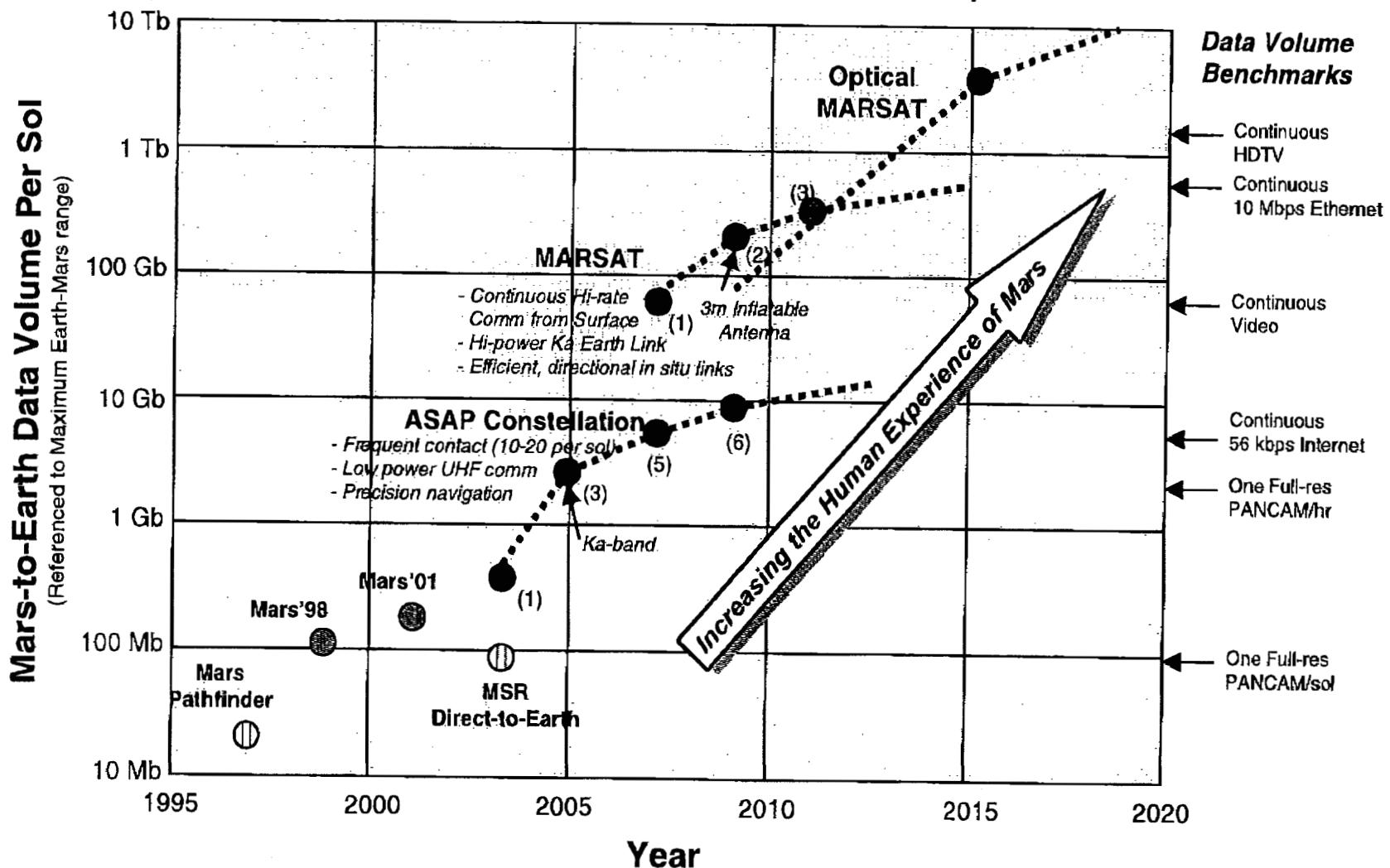


- **CCSDS Proximity-1 Link Protocol**
 - Specification of link layer protocol for short-range communications
 - Critical for ensuring interoperability among NASA, ESA, CNES, and ASI assets at Mars in the 2003 time frame
- **CCSDS File Delivery Protocol**
 - Provides FTP-like functionality, with reliable end-to-end file transfer over long-light-time, multi-hop relay links



Mars Network Evolution

- Aggressive technology infusion will allow orders-of-magnitude growth in communications capability, enabling radical increases in the fidelity of Mars virtual presence



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